# THE BACKBONE OF AIR FORCE FORECASTING: AIR WEATHER SERVICE INTEGRATION OF JOINT NUMERICAL WEATHER PREDICTION UNIT PRODUCTS, 1954-1959

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## 1. Introduction

On December 17, 1903, Orville and Wilbur Wright completed the first controlled, powered flight at Kitty Hawk, North Carolina. The Wrights went to Kitty Hawk because in their estimation it had the best "weather" for flying their fragile craft. Before launching their craft, the Wrights took careful notice of the prevailing winds. Orville Wright recorded in his diary that at the time of the first successful flight the wind was blowing at approximately 20 miles per hour. Since that day, aviation and meteorology have been undeniably linked.

The development of Army aviation in the first decades of the 20th century and its increasing demand for weather services led to the transfer of the Army's meteorology section from the Signal Corps to the Air Corps on July 1, 1937. Air Force leaders have long recognized the importance of meteorological support to their operations. In 1953, General George C. Kenney, commander of Strategic Air Command, claimed that "the nation which first learns to plot the paths of air masses accurately. . .will dominate the globe (quoted in Edwards, 225)."

Richard Reed remarked at the 57th Annual Meeting of the American Meteorological Society in 1977, that "[d]espite the many advances [in the first half of the 20th century,] weather forecasting remained essentially an art until the middle of [the 20th] century." He concluded that "[w]ith the advent of numerical [weather] prediction [weather forecasting] has become increasingly an exact science (Reed, p. 393)."

The Air Force's Air Weather Service, so designated in 1946 when the Army Air Forces consolidated most of its operational meteorological services in this single organization, had built a global meteorological network and incorporated many technological advances in meteorological observation, analysis, and forecasting during World War II. Yet, the Air Weather Service was still badly in need of more science than art in weather forecasting in the period that immediately followed World War II. The Air Force began planning for "all-weather" jet fleets during World

War II and saw the fruition of its programs soon thereafter. The Air Force requested development of the F-80 jet fighter in 1943. It received its first production aircraft in 1945. Similarly, the Air Force approved the swept-wing B-47 bomber design in 1944 and received its first operational jet bomber in 1950. These aircraft, and those that followed, flew higher, faster, and farther than military aircraft had previously. Although proposed as "all-weather," these aircraft in many ways required more timely, detailed, and accurate meteorological support than their predecessors.

Major General William O. Senter, commanding general of the Air Weather Service from 1950 to 1954, wrote in October 1952 in his quarterly update letter to the commanding general of the Military Air Transport Service, Lieutenant General Joseph Smith, that jet operations "made necessary a high degree of accuracy in terminal and alternate forecasts." He concluded that among the many requirements the Air Weather Service needed to support was "intensified research" into the "best available techniques for forecasting [that] are still experimental (Milner 1953, pp 245-250)."

Paradoxically at the very time Air Weather Service required more and better trained forecasters, its forecasting force was shrinking. Air Weather Service faced forecaster shortages due both to the post World War II and Korean War reductions in the overall force structure of the Air Force as well as difficulties in filling the authorized vacancies for forecasters. The jet age required in many ways more of Air Weather Service than had previously been asked and its leadership viewed the operationalizing and integration of Joint Numerical Weather Prediction Unit products as the best way to accomplish their mission for the U.S. Air Force.

## 2. Culture of Technology

The leadership of Air Weather Service fully supported and promoted the research, development, and employment of technologies and methodologies to operationalize numerical weather prediction. They envisioned these processes would free their limited force of forecasters from chart building and permit them to provide more direct, targeted forecasting to the commands they supported.

That the Air Weather Service looked to this new technology is not surprising. Stephen B. Johnson argues in his monograph *The United States Air Force and the Culture of Innovation* that "of the [U.S. armed] services, the Air Force [has] relied most heavily on academia and industry." Johnson states "since its inception the Air Force has depended on advanced technologies to maintain an edge over its actual and potential enemies. Continued innovation

became a way of life and Air Force leaders learned quickly to foster productive relationships among their service and the scientists, engineers, and industry leaders. . . .” Johnson summarizes that this relationship is “not terribly surprising. . .[w]hen we consider the criticality of advanced technology for air and space warfare (Johnson, 221-222).”

The Air Corps Weather Service became involved in meteorological research soon after its organization. In the fall of 1940, it became concerned that the U.S. Weather Bureau might not be adequately funded to address continued research in improved forecasting techniques (a concern that continued into the 1950s) and sent officers and funds to the Massachusetts Institute of Technology and the California Institute of Technology for advanced meteorological study and research. In the summer of 1941 it established the Army Air Forces Weather Research Center at Bolling Field in the District of Columbia. In addition to preparing climatology studies and special long-range forecasts, this group conducted research into the latest meteorological developments.

The Air Force’s general concern with advanced research was very evident during and after World War II. Commanding General of the Army Air Forces, General Henry H. “Hap” Arnold, codified the relationship between the scientific community and the Air Force during World War II. In 1944 Arnold called upon his long time friend and advisor, the noted physicist Theodore von Kármán, to be his scientific advisor. Von Kármán became director of the Army Air Forces Scientific Advisory Group, later renamed the Air Force’s Scientific Advisory Board.

In December 1945, von Kármán’s Scientific Advisory Group published a multi-volume blueprint for the post-war Air Force. These defining works highlighted the necessary relationship between the Air Force and academia with specific research programs the Air Force needed to pursue as an “all-weather force,” a term that came to be synonymous to many with the jet age. In a section of the first volume of the report, titled “Function Independently of Weather and Darkness,” the Scientific Advisory Group summarized, “Meteorology, the science of the atmosphere, is of ever-increasing importance to the military. To keep abreast of modern military developments, research in meteorology must be vigorously pursued.” The Group recognized the future potential in numerical weather prediction. The first volume foretold, “It seems possible, with the aid of electronic computers, to produce a model of a certain region of the earth’s surface and the existing weather situation, which can be used. . .for fast weather prediction (Gorn, p. 151).”

On July 1, 1954, the Joint Numerical Weather Prediction Unit, a combined U.S. Air Force, U.S.

Weather Bureau, and U.S. Navy numerical weather forecasting unit under the leadership of Air Force meteorologist Dr. George P. Cressman, was organized at Suitland, Maryland. From 1954 to 1959, much of the Air Weather Service's centralized forecasting efforts began to integrate the products produced and distributed by the Joint Numerical Weather Prediction Unit as a means of providing efficient, standardized forecasting for Air Force operations. The Air Weather Service historian recorded in his report for the last half of 1957 that the "creation of the Joint Numerical Weather Prediction Unit at Suitland in 1954, and the installation there of an IBM-701 electronic computer, ushered in what Air Weather Service regarded as a new era in forecasting (Flammer 1958, 87)."

Air Weather Service leadership believed that the potential efficiencies in weather forecasting being made possible through centralized numerical weather prediction were, in the words of Major General Thomas S. Moorman, Jr., the commander of Air Weather Service from 1954 to 1958, the "greatest prospect for substantial forecast improvement, both in quality and directness of application (Moorman, p. 6)." As early as mid-1956, Air Weather Service leadership began pushing for integration of Joint Numerical Weather Prediction Unit objective forecasts into the daily forecasting efforts of Air Weather Service. Moorman urged his commanders at a meeting in July 1956 "to evaluate continually the numerical weather prediction products available to you [and to] work with these prog[nose]s and find out how they can be integrated into your forecast service routine (Moorman, p. 6)."

## 3. Early Numerical Interest

By the late 1940s Air Weather Service's research interests included numerical weather prediction. In 1945 the Air Force sent Lieutenant Philip D. Thompson to the University of California at Los Angeles to study under Jacob A. B. Bjerknes. While there, Thompson, according to his later recollections, became interested in numerical weather prediction as a more viable alternative to the methods of forecasting then under study at the school. In 1946, Thompson convinced the director of Air Weather Service's research and development, Colonel Benjamin G. Holzman, to permit him to join the Meteorology Project at the Institute for Advanced Study at Princeton University. Thompson recalled that he often was the only researcher there during his nearly two-year tenure with the Meteorology Project (Thompson 1983, pp. 757-761). In *Calculating the Weather: Meteorology in the 20th Century*, Frederik Nebeker contends (p. 180), "It may have been Thompson's presence that kept the Project going."

In 1948 Thompson was detailed from the Air Force's central research and development center at Wright-Patterson Air Force Base, Ohio, to the Air Force Cambridge Research Laboratory, renamed the Cambridge Research Center in 1951. Beginning in 1949, a small group at the Cambridge Research Laboratory's Geophysics Research Directorate, renamed the Geophysics Research Division in 1951, began work under the supervision of Thompson that was similar to that Thompson had done at the Meteorology Project at Princeton. That same year, in 1949, the Air Force Cambridge Research Laboratory also began funding the Princeton group's research and development of numerical weather prediction, which had initially been endowed by the Office of Naval Research.

By 1951 Thompson's group at the Geophysics Research Division had to a certain degree moved beyond the work being accomplished at Princeton. Using a numerical prediction model they developed, Thompson's group computed a series of daily forecasts in 1951. According to Air Weather Service analysis, these forecasts compared most favorably with the subjective methods then in use by Air Force forecasters.

In January 1951, Senter wrote his superior at that time, Major General Laurence S. Kuter, commander of the Military Air Transport Service, to inform him that the Air Weather Service was "actively supporting a large number of projects aimed at improving the theoretical basis of meteorology." He also noted he was reorganizing the Air Weather Service headquarters Directorate of Scientific Services, which was formed in 1948 under the leadership of Sverre Petterssen, in order to "conduct a more vigorous program of evaluation" of the latest research for adoption in operational forecasting (Rodenbeck 1951, p. 128).

In mid-1952, Petterssen briefed Senter on a proposed Joint Geophysics Research Division-Air Weather Service Numerical Prediction Project. Senter approved the project. He and his staff recognized that the Air Weather Service was greatly in need of accelerated research and development toward producing numerical weather prediction forecasts on a regular basis if it was to ever provide adequate forecasting support for the modern Air Force.

## 4. Project DOORBELL

How to adequately support the growing Air Force jet operations was very much on the minds of Air Weather Service leaders in 1952. The flight characteristics of jet aircraft presented previously unheard of forecasting requirements.

In the estimation of key staff members at the Air Weather Service headquarters, the Geophysics Research Division was

the only institution with the necessary resources, including funding for an electronic computer, and the "previous experience and contact with the methods of numerical prediction" that could at that time orient its work toward regular production of numerical weather prediction (Milner 1953, p. 250).

In February 1953, the Air Force activated the Joint Geophysics Research Divison–Air Weather Service Numerical Weather Prediction Project, known within Air Weather Service by the nickname Project DOORBELL. Air Weather Service's 4th Weather Group, headquartered at Baltimore, Maryland, provided the personnel to support the effort through its detachment at Hanscom Air Force Base, Massachusetts. Thompson, now on detached service from the 4th Weather Group to the Geophysics Research Division, was assigned as the project director.

The objectives of the Air Force's Numerical Weather Prediction Project, as stated by Thompson in early 1954, were to develop and standardize procedures, based on existing or anticipated methods of numerical prediction, for producing forecasts on a regular basis; to establish the overall accuracy and computational demands of several existing methods, by applying them to a representative sample of weather situations; to provide a basis for estimated requirements of an operational numerical prediction unit, and to train, through on-the-job contact with the methods of numerical prediction, a group of people who might later form part of an operating staff (Thompson 1954, p. 1).

Furthermore, Senter and his staff began a series of steps in mid-1953 to get numerical weather prediction operationalized as a joint venture among the three U.S. weather services. Robert D. Fletcher, head of Air Weather Service's Scientific Services directorate from 1952 to 1971, recalled in a 1972 interview (p. 13-14) that Senter liked to summarize how the Joint Numerical Weather Prediction Unit came into being by saying that the Navy started the funding for the research, the Air Force wrote the proposal, and the Weather Bureau read the paper.

As apparently agreed between Senter and U.S. Weather Bureau chief, Francis W. Reichelderfer, in May 1953 the U.S. Weather Bureau member of the Joint Meteorological Committee proposed that a special subcommittee investigate the possibilities of operationalizing numerical weather prediction. The Joint Meteorological Committee accepted the proposal to investigate numerical weather prediction with an amendment the Air Weather Service representative presented that the subcommittee should additionally plan for the establishment of an operational numerical weather prediction center. General Senter wanted the Weather Bureau to introduce the proposal in order to ensure the Weather Bureau's support of such a project (Fletcher, pp. 13-14).

It is debatable how the three services arrived at a mutually satisfactory arrangement for staffing and funding the Joint Numerical Weather Prediction Unit once the Joint Meteorological Committee approved the project. According to the Air Weather Service record, it appeared to Senter from his discussions with representatives of the Navy and U.S. Weather Bureau that both services were supportive of having an equal share in operating the project, but neither seemed at first willing to bear a proportionate share of the cost of operating such a unit. In the Air Weather Service historian's estimation the Weather Bureau acquiesced relatively quickly to Senter's pressure for proportional funding; however, General Senter had to more strongly make his point to the Navy that if Air Weather Service funded more than one-third of the project, it would insist upon "a lion's share of control (Milner 1953, p. 287)."

Fletcher remembered (pp. 13-14) that the Weather Bureau was the harder of the two services to convince. He stated that Henry Wexler, Reichelderfer's lead on numerical weather prediction at the U.S. Weather Bureau, while strongly supporting numerical weather prediction research, didn't think the time was yet ready for pursuing operationalizing of numerical weather prediction.

In June 1954, one month before the Joint Numerical Weather Prediction Unit was activated and after nearly two years of continued research and development, the Joint Geophysics Research Division–Air Weather Service Numerical Weather Prediction Project completed a series of sixty (or 120 by Thompson's accounting method) consecutive numerical weather prediction forecasts. Air Weather Service observers considered these forecasts to be "the most complete and systematic test to which any method of numerical prediction [had] been subjected" to at that time. These objective numerical weather prediction forecasts were compared with subjective forecasts for the same general period that had been prepared at the Air Force Weather Central located at Andrews Air Force Base, Maryland, and were found to be "superior." In sum, the leadership of Air Weather Service was convinced with the organization of the Joint Numerical Weather Prediction Unit that numerical weather prediction was ready for integration into the forecasting for Air Force operations.

## 5. Product Integration

The efforts of the Joint Numerical Weather Prediction Unit were stymied for nearly a year until its computer was installed and operational. In the first half of 1956, Air Weather Service distributed to all its units Technical Report 105-120, "An Introduction to Numerical Weather Prediction

(Selka, p. 115)." By the closing months of 1956, Air Weather Service forecast centrals had begun to receive Joint Numerical Weather Prediction Unit products and had begun to replace their own prognosis preparation with the charts prepared at the Joint Numerical Weather Prediction Unit. In 1956 the Joint Numerical Weather Prediction Unit's 72-hour barotropic 500-millibar prognosis replaced the product that had been prepared by the Air Force Weather Central for distribution on the Air Force's continental United States weather facsimile network.

The level of integration grew through the remainder of the 1950s to the point where the conclusion contained in a Air Weather Service presentation prepared in 1959 was that Air Weather Service units had increasingly becoming dependent upon numerical products and that the Joint Numerical Weather Prediction Unit had grown by that time "to be the forecasting backbone of the national meteorological service. . . (Joint Numerical Weather Prediction Program, p. 2)."

By 1959, Air Weather Service was integrating the Joint Numerical Weather Prediction Unit's 300-millibar, 500-millibar, and 700-millibar prognoses, vertical motion and absolute vorticity charts to some degree at nearly all its forecasting stations. Through first-level integration of these products at the theater-level Air Weather Service weather centrals, nearly every Air Weather Service forecaster was using Joint Numerical Weather Prediction Unit products directly or indirectly.

The Air Weather Service's European Weather Central at High Wycombe, England, began receiving 24-, 48-, and 72-hour 500-millibar numerical weather prognoses from the Swedish Meteorological Office in Stockholm, Sweden, in December 1955. The initial expectations for these products were high, but short-lived. In May 1956 the European Weather Central ended the experiment, when it determined that the Swedish prognoses were "slightly inferior to those made by [personnel of the European Weather Central] (28th Weather Squadron January-June 1956, p. 58)."

However, by early 1957, the leadership at the High Wycombe central had confirmed for themselves that the Joint Numerical Weather Prediction Unit prognoses were "slightly more accurate in forecasting patterns and wind factors than those put out by [the] center or local detachments." The organization's historian reported "increasing use is being made of the numerical prog[nose]s from Washington (28th Weather Squadron January-June 1957, p. 47 and 28th Weather Squadron July-December 1957, p. 33)."

By 1959, the European Weather Central relied almost exclusively on Joint Numerical Weather Prediction Unit products. The leadership at

High Wycombe at that time believed that they could not improve upon the Joint Numerical Weather Prediction Unit prognoses and used them directly as their briefing and forecasting charts. They used the central's forecasting staff for product backup in case the Joint Numerical Weather Prediction Unit products were not available and for interpretation of these products to their customers.

Similarly, the Offutt Weather Central moved towards full integration of Joint Numerical Weather Prediction Unit products into its support of the Strategic Air Command. In the first half of 1955, prior to the distribution of Joint Numerical Weather Prediction Unit charts, the Offutt Weather Central had already begun to eliminate duplicative chart development. It began using National Weather Analysis Center products directly from the facsimile circuits for the western half of the northern hemisphere; thereby, permitting the staff to concentrate on the eastern half of the northern hemisphere, which required more effort due to its unfamiliarity (Wren, p. 54.)

With the closure of the Air Force Weather Central, which had moved to Suitland, Maryland, in 1955, and the assumption of its mission by the Offutt Weather Central in the first of 1958, the workload for the Offutt Weather Central, renamed the Global Weather Central, continued to grow. In 1958, a comparison of 300-millibar charts produced at the Global Weather Central with Joint Numerical Weather Prediction Unit products showed no significant differences (Corbet 1959, Appendix 1, 12) and by 1959 the Joint Numerical Weather Prediction Unit product had been substituted for the Global Weather Central product (Stern 1959, Appendix 1, 8).

In 1959, Global Weather Central began development of its own centralized computer products. In February Major Harold "Art" Bedient of the Joint Numerical Weather Prediction Unit visited the Global Weather Central. His meetings with Global Weather Central personnel determined the Central's requirements for Joint Numerical Weather Prediction Unit products in the development of the Global Weather Central's computer products. The following month, Global Weather Central began output of improved computer products and began discussions of direct computer-to-computer interface between the Joint Numerical Weather Prediction Unit and the Global Weather Central computers.

Global Weather Central personnel continued comparison of its products with those of the Joint Numerical Weather Prediction Unit. The leadership of the Global Weather Central concluded "[c]omphrensive evaluation of the procedures and products of [the Joint Numerical Weather Prediction U]nit has clearly established the reliability of such computers as forecasting tools." "With the introduction of new weapon

systems, Strategic Air Command's requirements for weather support [had] become more stringent, demanding higher and higher altitude information delivered in ever decreasing time intervals. To fully meet these requirements, Global Weather Central had to go more into an automated electronic data processing system (Stern 1959, Appendix 1, 5)."

The Tokyo Weather Central was similarly integrating weather products by the late 1950s. In an interview printed in the October 1959 issue of Air Weather Service's command newspaper, Lt Col Arthur M. Longacre, chief of the Tokyo Weather Central's Analysis and Forecasting section, stated the Tokyo Weather Central's relationship with the Joint Numerical Weather Prediction Unit had become one of being "mostly middlemen." The colonel explained, "[T]ests have shown that the JNWP pressure height patterns are more accurate than the average good forecaster can produce." "It is this complex inter-relationship [of global weather patterns] that can be best handled by the electronic brain—and much faster (Waltry)." Taking the Joint Numerical Weather Unit products they received via teletype the Tokyo Weather Central forecasters constructed pressure height pattern charts for 12-, 24-, 36-, 48-, and 72-hour prognoses.

It was not that Air Weather Service personnel believed the Joint Numerical Weather Prediction Unit products were flawless. In fact, Air Weather Service leaders fully appreciated the limitations of these products. Rather, Air Weather Service leadership found that the Joint Numerical Weather Prediction Unit products were as good as could be expected given the state of meteorology and computing at that time. They were willing to live with the products at hand while devoting more resources to research and development for future forecasting improvements.

The leadership of Air Weather Service was seemingly in complete agreement with Cressman's evaluation of the Joint Numerical Weather Prediction Unit products. Before the Joint Meteorological Group in May 1959, Cressman stated, "The numerical forecasts for levels from 700 to 300 millibars inclusive are significantly better than independent subjective forecasts. Skilled forecasters given the numerical forecasts can improve on them only very slightly or not at all (Thompson 1959, p. 4)."

## 6. Conclusion

Air Weather Service leadership was convinced of the value of operational numerical weather prediction. By mid-1955, they had already agreed that "[w]hatever the cost, the service was worth it." They were assured that "[c]ertainly the benefit to the forecaster would be immense. It would give him a service never available before. It

would substitute for subjective estimates of what the atmosphere would be like in the future, scientifically processed data which would predict its make-up by numerical methods and with a very high degree of accuracy (Milner 1955, p. 181)."

Air Weather Service leadership saw direct benefits from integrating Joint Numerical Weather Prediction Unit products as quickly as possible into its operations. Forecasters would be relieved of routine map work to concentrate their efforts on the increasing demands of specialized customer support in the jet age. An Air Weather Service policy statement for the operational utilization of Joint Numerical Weather Prediction Unit products stated the goal clearly, "As Joint Numerical Weather Prediction products are accepted, resources released will be diverted to meet the requirement for interpretation of prognostic charts, for example, to present the. . .distribution of operationally significant weather elements (Policy for Operational Utilization, p. [1])."

Air Weather Service commander, Major General Thomas S. Moorman, Jr., summarized the problems facing Air Weather Service for his senior commanders in October 1957. At his annual commanders' conference, Moorman reported, "[I]n view of probable reductions in manpower authorizations, I felt that we should start thinking about new ways to do things." "We must, of course consider this same manpower problem," he continued, "in connection with new and additional requirements for weather support to newer, faster aircraft and all types of missiles, the possible large-scale strategic and tactical use of nuclear weapons, [and] the employment of the increased capability of automation (1957 Air Weather Service Commander's Conference, p. 4)."

In hindsight it might be argued that the leadership of the Air Weather Service was overly optimistic in its vision that numerical weather prediction was ready for rapid integration in the 1950s. However, as Frederick Shuman concluded (p. 287) in his 1989 article the "History of Numerical Weather Prediction at the National Meteorological Center," had integration into operation forecasting not been pursued at that time, the efforts toward numerical weather prediction to that time might well have failed. Shuman concluded, "The operational environment was the appropriate environment for the early problems to be quickly encountered and solved."

In 1959, Air Weather Service, in cooperation with the Military Air Transport Service, began using Joint development of computer-generated flight plans based upon numerical weather prediction and the products of the Joint Numerical Weather Prediction Unit. Air Weather Service's confidence in numerical weather prediction lead

to the formation of the Air Force Global Weather Central at Offutt Air Force Base to begin serving the forecast needs of not just the Strategic Air Command, but the entire United States Air Force. Today's strategic forecasting center at the Air Force Weather Agency traces its heritage directly to that confidence displayed by the leadership of the Air Weather Service in numerical weather prediction in the 1950s. Lt Col Dillard Thompson, chief of Headquarters Air Weather Service's Operational Analysis division summarized the state of numerical weather prediction within Air Weather Service in 1959. Thompson concluded, "[I]t seems to me we have achieved more experience with the entire numerical weather prediction process. We know more about our limitations and capabilities in this direction (Thompson 1959, p. 1)." "Certainly, all this indicates that within a short while numerical weather prediction has moved into the heart of Air Weather Service, and perhaps, Air Force, operations [as a whole] (Thompson 1959, p. 8)."

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